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In Indiana sweet colored pepper is a very lucrative crop grown mostly by small growers for local consumption. The average land per farm allocated to the production of bell peppers was 0.68 acres and other peppers (including chile) 1.16 acres. In total 263 harvested bell and 280 other pepper acres were recorded during the 2017 Census of Agriculture (USDA NASS, 2019). High tunnel production of vegetables is very popular and the technology allows growers to extend the production season, especially for warm-season crops, and also protect their crop against severe environmental conditions. Sweet colored bell and tapered peppers can yield well in an unheated high tunnel. Growing sweet peppers to full maturity takes longer but reward the grower financially. Information is lacking about which varieties are adapted for high tunnel production and their performance. This paper reports on ten colored sweet bell and tapered pepper entries (Table 1; Figures 7 – 16) that were evaluated at the Purdue Student Farm, West Lafayette, Indiana.

Materials and Methods

The trial was conducted on a Mahalasville (Md), silty clay loam. The spring soil test showed 5.6% organic matter, pH 7.7, and 112 ppm phosphorus (P), 127 ppm potassium (K), 564 ppm magnesium (Mg), and 2687 ppm calcium (Ca). The cation exchange capacity was 18.5 meq/100 gram. Nitrogen, 60 lb./A N from Nature's Source® Professional 10-4-3 liquid plant food, was applied by fertigating 15 lb./A N four times at 2, 4, 6, and 8 weeks after transplanting. Additionally, 5 lb/A N was applied as $Ca(NO_3)_2$ three weeks after transplanting.

The trial was set up in a high tunnel that was 30 feet wide and 96 feet long (Nifty Hoops, MI) as a randomized complete block design with six replications (Fig. 3-6). The high tunnel was equipped with louvered gable vents (one at each end wall) and roll-up sidewalls. The gable vents were permanently open, but the side walls were opened when inside temperatures reached 75 °F and closed when temperatures dropped below 60 °F. Sweet pepper entries were assigned to individual plots containing one row of five plants that was 7.5 feet long. Peppers were seeded April 12, 2019, and transplanted into raised beds (2 feet wide) on May 13, 2019, with an in-row spacing of 1.5 feet and between-row spacing of 4 feet. (7,260 plants per acre). The entire area between the raised beds (4 feet center-to-center) was covered with a black woven polypropylene ground cover (DeWitt Sunbelt™). Additionally, a 3 feet wide white woven polypropylene groundcover was placed between the rows to increase light in the lower plant canopy. Irrigation was applied once per day using 2 gallons per hour pressure-compensated emitters (Netafim), flex vinyl spaghetti tubing, and 90-degree angle stakes.

Nature's Source® Professional 10-4-3 liquid plant food was mixed in a concentrated stock tank at 100 times the normal concentration and injected at a 1:100 rate using a water-powered Dosatron D14MZ2 injection unit. Initial plant support was provided with a stake and weave trellis system. Additionally, plants were treated with a biological fungicide BotryStop™

(BioWorks®) at a rate of 3 lb./A dissolved in 100 gallons water and Rootshield™ (BioWorks®) at 6 oz per 100 gallons water. The treatments were applied through the irrigation system. No pruning was done during the growing season. Weed control was minimal and done by hand. OMRI listed Sluggo™ snail bait was applied within the first week after transplanting for the control of slugs. Yellow and blue sticky cards were used for scouting and monitoring and to attract and capture the adult life stage of insect pests. Pest pressure was very low and therefore no foliar pesticide applications were done during the growing season.

Each plot was harvested after the peppers reached their mature color. Harvesting continued once a week between 87 and 151 days after transplanting. For each plot, the marketable and unmarketable number of fruits, fruit weight, fruit size (length and width), and flesh thickness were recorded. During the last harvest (October 11, 2019) all mature colored and mature green fruit were harvested and recorded. The marketable yield was expressed as yield per plant or yield per acre. Data were analyzed using ANOVA followed by treatment means separation using Tukey-Kramer's least significant difference at $P \leq 0.05$.

Results and Discussion

Results for yield and fruit size are presented in Table 2. The number of fruits per plant and fruit weight differences among entries was highly significant ($P<.0001$). Carmen produced the highest number of fruits per plant (43.7), significantly higher than any bell pepper entry and tapered pepper entries Giubileo (28), Marcato (27.4), and Mattadores (26.5). There was no significant difference in fruit number per plant between Carmen and Escamillio (36.6), both tapered pepper varieties. Of the bell peppers, Chesapeake produced the highest number of fruits per plant (30.2). However, fruit yields of other bell pepper varieties Zamboni, Flavorburst, Vanguard, and Red Knight varied between 17.7 and 27.1 per plant and were not significantly lower than Chesapeake. Bell pepper entries producing significantly heavier fruit included Vanguard (10.5 oz), Red Knight (7.9 oz), and Flavorburst (6.6 oz). Tapered pepper varieties produced significantly smaller fruit, especially Escamillo (4.8 oz) and Carmen (3.8 oz). All entries evaluated did not produce significantly different yields per plant. Total yield per plant varied between 9.4 and 11.2 lb./plant. Although differences among entries in terms of yield per plant and acre were not significant at $P<0.05$, bell pepper entries Chesapeake, Vanguard, and Flavorburst produced >80,000 lb./A yields. Tapered pepper yields varied between 70,000 and 79,000 lb./A, with Escamillo producing the highest yield.

Bell and tapered pepper fruit characteristics (fruit length, width, and shape) were recorded (Table 3). The longest fruit was produced by Giubileo (10.3 inches), followed by Mattadores and Marcato (7.9 and 7.8 respectively). Peppers were classified according to fruit shape. As expected, all tapered pepper entries were classified as elongated. However, bell pepper varieties Red Knight and Flavorburst were also classified as elongated, Chesapeake and Zamboni as very blocky (flattened shape), and Vanguard as blocky (Figures 7 – 16).

Tapered pepper results were affected by a higher number of unmarketable fruit (Table 4, and Figures 1 and 2). Fruit culls were mainly as a result of blossom end rot (BER). Most culls (fruit per plant) were observed in the tapered pepper entries, especially Giubileo (7.4) and Carmen (6.7). Bell pepper culls were limited to between 0.5 and 1.3 fruit per plant. The percent of BER culls, as it relates to total unmarketable fruit, ranged from 14 to 63% for bell pepper entries, and 70 to 92% for the tapered pepper entries. Vanguard and Red Knight, the largest and second-largest fruit-producing bell pepper varieties, were the most affected by BER. BER culls as a

percent of the total marketable fruit harvested, ranged from 0.4 to 5.4% for bell pepper varieties and 10.1 to 24% for tapered pepper varieties. Some fruit was affected by bacterial soft rot but did not have a significant effect on yield.

All varieties performed well under high tunnel conditions. Varieties producing lower fruit numbers per plant are usually yielding larger fruit. Vanguard (red bell) produced about 17 fruit per plant but produced jumbo-sized fruit at 10.5 ounces and that translated to a whopping 81,500 lb./A yield. On one occasion, we recorded a Vanguard pepper weighing 18.6 oz. Chesapeake (red bell) and Flavorburst (yellow bell) are some of the top performers in terms of fruit number and size. Flavorburst is least affected by BER and is one of the early yielders that continues to produce fruit all season long, even though it is a relatively compact plant. Carmen (red tapered) and Escamillo (yellow tapered counterpart to Carmen) outperformed other tapered pepper varieties in terms of fruit number and produced >75,000 lb./A yields. Both varieties produced fruit that is about 6.5 inches long, 1.5 to 4 inches smaller than the other tapered entries. Giubileo (yellow tapered) produces beautiful fruit but the very long fruit (>10 inches) makes the variety prone to BER under suboptimal growing conditions. Growers have a wide selection of varieties to choose from. Assess your market and choose varieties accordingly.

Acknowledgments

Chris Adair and students who provided on-farm support.

Reference

USDA NASS 2019. 2017 Census of Agriculture. Accessed on December 8, 2020. https://www.nass.usda.gov/Publications/AgCensus/2017/index.php

Table 1. Colored sweet bell and tapered pepper cultivar characteristics*.

Cultivar	Type	Days to Maturity	Immature Fruit Color	Mature Fruit Color	Recommended Production Condition
Chesapeake	Bell Pepper	72	green	red	open field
Zamboni	Bell Pepper	70	green	red	greenhouse
Flavorburst	Bell Pepper	87	lime green	yellowish-orange	high tunnel
Vanguard	Bell Pepper	75	dark green	red	open field
Red Knight	Bell Pepper	66	dark green	red	open field
Marcato	Tapered Pepper	70	green	red	open field
Carmen	Tapered Pepper	80	green	red	open field
Escamillo	Tapered Pepper	80	green	golden-yellow	open field
Mattadores	Tapered Pepper	70	deep green	red	open field
Giubileo	Tapered Pepper	80	dark green	yellow	open field

*Data obtained from seed company listed information

Table 2. Marketable yield of colored sweet bell and tapered pepper cultivars in west-central Indiana.

Cultivar	Number of fruits per plant [z]	Number of fruits per Acre [z]	Fruit Weight (oz) [z]	Yield (lb/plant) [z]	Yield (lb/Acre) [z]
Chesapeake	30.2 bcd	219,494 bcd	5.9 cd	11.2 a	81,120 a
Zamboni	20.9 cd	151,734 cd	7.4 b	9.6 a	69,809 a
Flavorburst	27.1 bcd	196,686 bcd	6.6 c	11.0 a	80,175 a
Vanguard	17.1 d	124,328 d	10.5 a	11.2 a	81,524 a
Red Knight	20.3 cd	147,257 cd	7.9 b	9.9 a	72,105 a
Marcato	27.4 bcd	198,924 bcd	5.7 d	9.7 a	70,719 a
Carmen	43.7 a	316,899 a	3.8 f	10.4 a	75,379 a
Escamillo	36.6 ab	265,474 ab	4.8 e	10.9 a	78,855 a
Mattadores	26.5 bcd	192,269 bcd	5.7 d	9.4 a	68,105 a
Giubileo	28.0 bcd	203,038 bcd	5.8 d	10.1 a	73,555 a
Pr > F	*<.0001*	*<.0001*	*<.0001*	*NS* [y]	*NS* [y]

[z] Means followed by the same letter are NOT significantly different at $P = 0.05$, Tukey-Kramer.

[y] NS – not significant

Table 3. Colored sweet bell and tapered pepper fruit characteristics.

Cultivar	Fruit Length (inch) [z]	Fruit Width (inch) [z]	Fruit Shape [y]	Fruit Shape Classification [y]
Chesapeake	3.7 d	3.7 ab	0.98 c	very blocky
Zamboni	3.6 d	3.8 ab	0.96 c	very blocky
Flavorburst	4.2 d	3.4 bc	1.21 c	elongated
Vanguard	4.0 d	4.0 a	1.02 c	blocky
Red Knight	3.7 d	3.2 cd	1.14 c	elongated
Marcato	7.8 b	3.0 cde	2.62 b	elongated
Carmen	6.3 c	2.3 fe	2.74 b	elongated
Escamillo	6.5 c	2.6 fe	2.54 b	elongated
Mattadores	7.9 b	2.8 de	2.82 b	elongated
Giubileo	10.3 a	2.9 de	3.58 a	elongated
Pr > F	*<.0001*	*<.0001*	*<.0001*	

[z] Means followed by the same letter are NOT significantly different at $P = 0.05$, Tukey-Kramer.
[y] Length to diameter ratio; ≤0.95: very blocky, flattened shape; 1.00: blocky, length equal to diameter; ≥1.05: an elongated shape with length greater than the diameter.

Table 4. Unmarketable yield of colored sweet bell and tapered pepper cultivars in west-central Indiana.

Cultivar	Total number of fruits per plant [z]	Number of BER fruits per plant [z]	Yield (lb/plant) [z]	Yield (lb/Acre) [z]
Chesapeake	1.2 cde	0.2 d	0.27 cde	1,973 cde
Zamboni	0.5 e	0.1 d	0.17 de	1,265 de
Flavorburst	0.5 e	0.1 d	0.14 e	1,036 e
Vanguard	1.3 cde	0.9 cd	0.59 bcde	4,319 bcde
Red Knight	1.0 de	0.7 d	0.34 bcde	2,465 bcde
Marcato	3.2 cde	2.9 cd	0.87 cd	6,297 cd
Carmen	6.7 ab	6.2 ab	0.98 b	7,136 b
Escamillo	4.0 bc	3.6 bc	0.86 bc	6,251 bc
Mattadores	3.7 cd	2.6 cd	0.85 bcd	6,139 bcd
Giubileo	7.4 a	7.0 a	1.85 a	13,460 a
Pr > F	*<.0001*	*<.0001*	*<.0001*	*<.0001*

[z] Means followed by the same letter are NOT significantly different at $P = 0.05$, Tukey-Kramer.

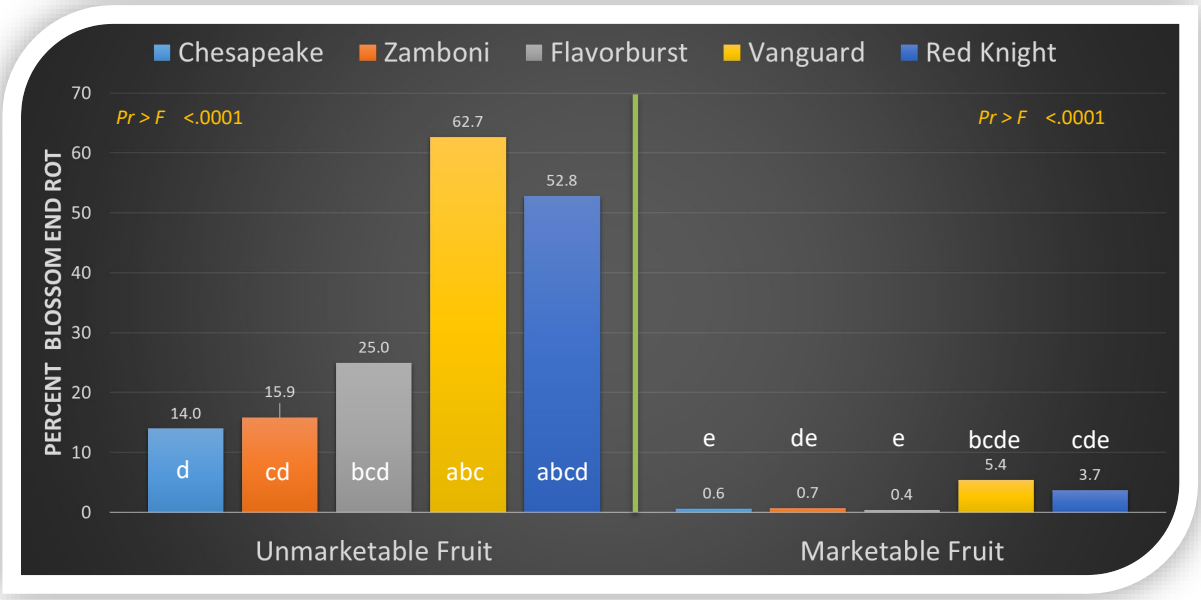

Figure 1: BER of colored sweet bell pepper cultivars showed as a percent of unmarketable (left) and marketable (right) fruit.

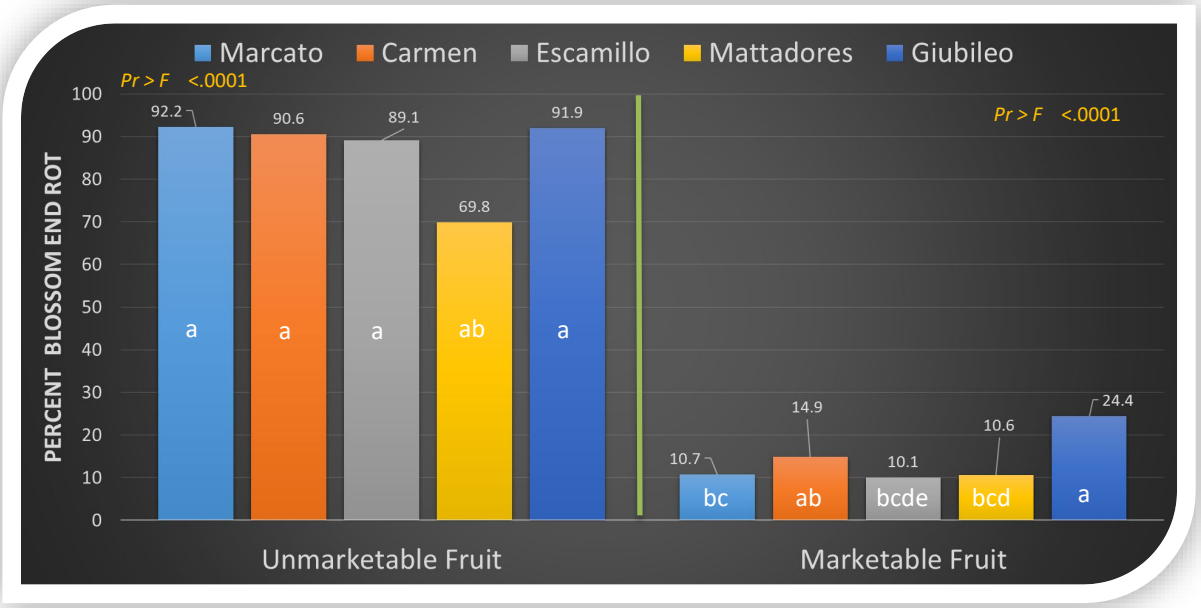

Figure 2: BER of colored sweet tapered pepper cultivars showed as a percent of unmarketable (left) and marketable (right) fruit.

Figure 3: Soil prepared, irrigation and crop support system installed in the high tunnel

Figure 4. High tunnel layout, 4 weeks after transplanting

Figure 5. Crop progress, 6 weeks after transplanting

Figure 6. Crop progress, 10 weeks after transplanting

Figure 7. Chesapeake

Figure 8. Zamboni

Figure 9. Flavorburst

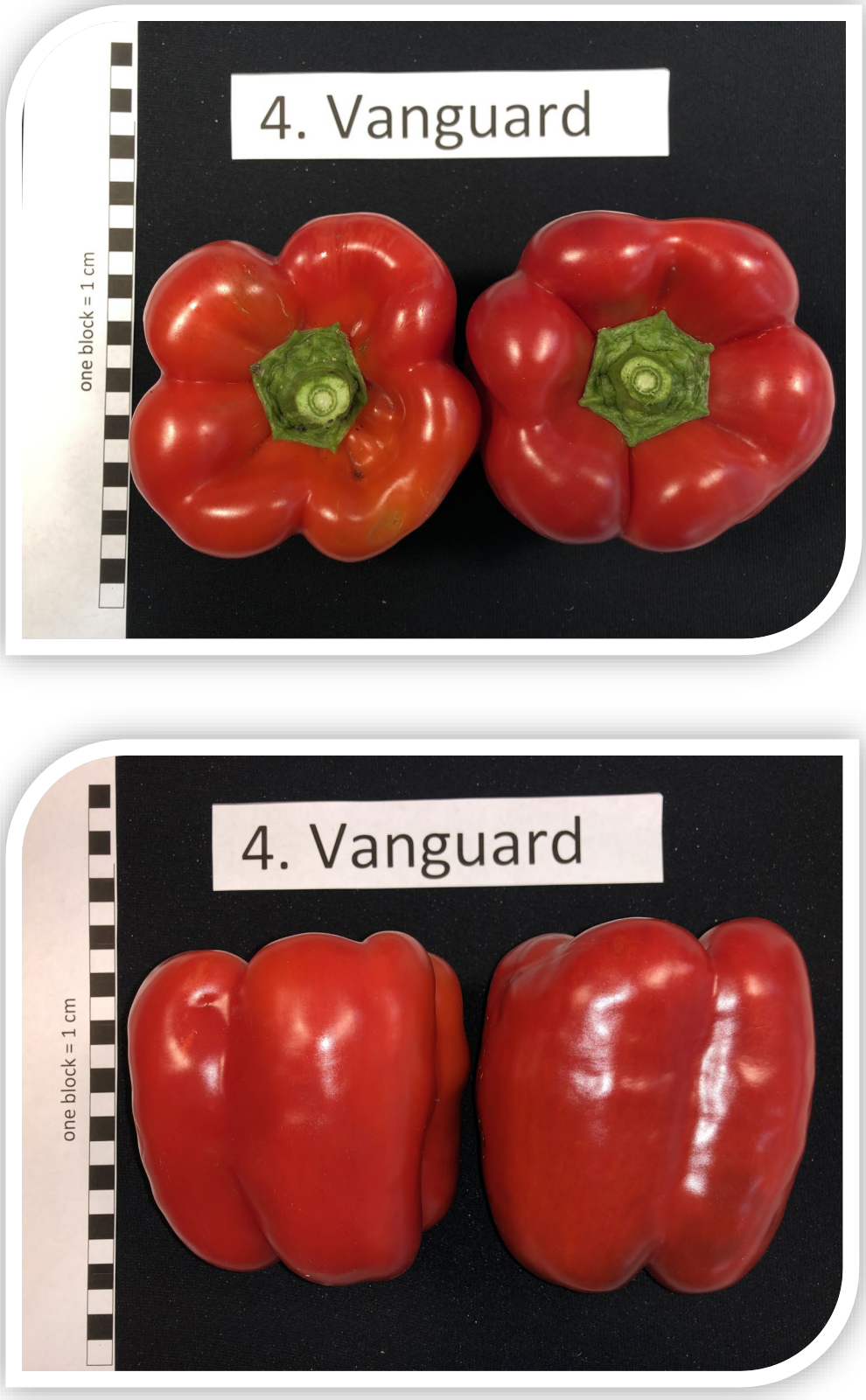

Figure 10. Vanguard

Figure 11. Red Knight

Figure 12. Marcato

Figure 13. Carmen

Figure 14. Escamillo

Figure 15. Mattadores

Figure 16. Giubileo